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Our ref: 0751-10171-US/final/Vincent

What is claimed is:

1. A method for I/Q imbalance calibration of a transmitter, comprising the steps of:

initializing parameters A_p, B_p and γ_p;

estimating a loop delay factor L;

generating a test signal $x[n]=x(n\cdot T_s)$, wherein $x(t)=e^{j\omega_T t}$ and ω_T is a preset radian frequency and T_s is sampling interval;

generating a compensated signal $x_{com}[n]$ by compensating the test signal $x[n]$ according to a first function with parameters A_p, B_p and γ_p;

converting the compensated signal $x_{com}[n]$ to an analog signal $x_{com}(t)$;

applying I/Q modulation to the analog signal $x_{com}(t)$ and outputting a modulated signal $x_{mod}(t)$;

obtaining a characteristic signal $x_c(t)$ of the modulated signal $x_{mod}(t)$;

obtaining a sampled characteristic signal $x_s[n]$ by sampling the characteristic signal $x_c(t)$ and obtaining statistics U_1 and U_2 of the sampled characteristic signal $x_s[n]$, where U_1 and U_2 are values indicative of the frequency response of $x_c(t)$ at radian frequency ω_T and $2\omega_T$, respectively; and

updating the parameters A_p, B_p and γ_p respectively by one of the second functions, the loop delay factor L, the statistics U_1 and U_2, and the current values of the parameters A_p, B_p and γ_p.

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2. The method as claimed in claim 1, wherein the step of estimating the loop delay factor further comprises the steps of:

generating a test signal $x'[n]=\cos(\omega_T nT_s)+\gamma_T$ which is a discrete-time signal and γ_T is a predetermined number;

converting the test signal $x'[n]$ to an analog signal $x'(t)$;

applying I/Q modulation to the analog signal $x'(t)$ and outputting a modulated signal $x'_{mod}(t)$;

obtaining a characteristic signal $x'_c(t)$ of the modulated signal $x'_{mod}(t)$;

obtaining a sampled characteristic signal $x'_s[n]$ by sampling the characteristic signal $x'_c(t)$ and obtaining a statistics V of the sampled characteristic signal $x'_s[n]$, where V is a value indicative of the frequency response of $x'_c(t)$ at radian frequency ω_T; and

estimating the loop delay factor L based on the statistics V.

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3. The method as claimed in claim 2, wherein the statistics V is obtained by taking FFT of the sampled characteristic signal $x'_s[n]$.

4. The method as claimed in claim 3, wherein the estimated loop delay factor L is $V/|V|$.

5. The method as claimed in claim 1, wherein the first function is $x_{com}[n]=A_p\cdot x[n]+B_p\cdot x^*[n]-\gamma_p$.

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6. The method as claimed in claim 1, wherein the statistics U_1 and U_2 are obtained by taking FFT of the sampled characteristic signal $x_s[n]$.

7. The method as claimed in claim 1, wherein the parameters A_p, B_p and γ_p are updated by the steps of:

computing the updated A_p based on the current A_p and B_p, the loop delay factor L, and the statistic U_2;

computing the updated B_p based on the current A_p and B_p, the loop delay factor L, and the statistic U_2; and

computing the updated γ_p based on the current γ_p, the loop delay factor L, and the statistic U_1.

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8. The method as claimed in claim 1, wherein the second functions for updating the parameters A_p, B_p and γ_p are:

$$A_p^{'} = A_p - \mu \cdot B_p \cdot U_2^{*} \cdot L \cdot L \ ;$$

$$B_p^{'} = B_p - \mu \cdot A_p \cdot U_2 \cdot (L \cdot L)^{*} \ ; \text{ and}$$

$$\gamma_p^{'} = \gamma_p + \mu \cdot U_1 \cdot L^{*} \ ;$$

where $A_p^{'}$, $B_p^{'}$ and $\gamma_p^{'}$ are the updated values, A_p, B_p and γ_p are the current values, and μ is a preset step size parameter.

9 ~~10~~. The method as claimed in claim 1, wherein the characteristic signal is derived by taking the square of an envelope of the modulated signal.

10 ~~11~~. The method as claimed in claim 2, wherein the characteristic signal is derived by taking the square of an envelope of the modulated signal.

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11 ~~12~~. An apparatus for I/Q imbalance calibration in a transmitter comprising:

a discrete-time signal generator generating a first test signal $x_1[n]=\cos(\omega_T nT_s)+\gamma_T$, where ω_T is a preset radian frequency, T_s is a predetermined sampling interval, and γ_T is a predetermined number, in an estimation phase, and generating a second test signal $x_2[n]=e^{j\omega_T nT_s}$ in a calibration phase which follows the estimation phase;

a correction module receiving the test signal from the signal generator, compensating the test signal according to a first function with parameters A_p, B_p and γ_p to produce a compensated signal;

a first and second D/A converter converting the compensated signal to an analog signal, wherein the first D/A converter converts the real part of the compensated signal to the real part of the analog signal, and the second D/A converter converts the imaginary part of the compensated signal to the imaginary part of the analog signal;

a modulator applying I/Q modulation to the analog signal, and outputting a modulated signal;

a detector obtaining a characteristic signal of the modulated signal;

an A/D converter converting the characteristic signal to a sampled characteristic signal; and

a processor implementing the steps of:

initializing the parameters A_p, B_p and γ_p;

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obtaining a statistic V based on the sampled characteristic signal in the estimation phase, where V is a value indicative of the frequency response of $x_c^{*}(t)$ at radian frequency ω_T;

estimating a loop delay factor L based on the statistic V in the estimation phase;

obtaining statistics U_1 and U_2 based on the sampled characteristic signal in the calibration phase, where U_1 and U_2 are values indicative of the frequency response of $x_c(t)$ at radian frequency ω_T and $2\omega_T$, respectively; and

updating the parameters A_p, B_p and γ_p based on the loop delay factor L, the statistics U_1 and U_2, and the current values of the parameters A_p, B_p and γ_p in the calibration phase.

~~13~~ 12. The apparatus as claimed in claim ~~12~~ 11, wherein the statistics V are obtained by taking FFT of the sampled characteristic signal in the estimation phase.

~~14~~ 13. The apparatus as claimed in claim ~~12~~ 11, wherein the loop delay factor L is $V/|V|$.

~~15~~ 14. The apparatus as claimed in claim ~~12~~ 11, wherein the first function is $x_{com}[n]=A_p \cdot x[n]+B_p \cdot x^{*}[n]-\gamma_p$, where $x[n]$ and $x_{com}[n]$ denote the test signal and the compensated signal, respectively, and $x[n]= x_1[n]$ in the estimation phase, $x[n]= x_2[n]$ in the calibration phase.

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15 ~~16.~~ The apparatus as claimed in claim 11 ~~12~~, wherein the statistics U_1 and U_2 are obtained by taking FFT of the sampled characteristic signal in the calibration phase.

16 ~~17.~~ The apparatus as claimed in claim 11 ~~12~~, wherein the processor updates the parameters A_p, B_p and γ_p by the steps of:

computing the updated A_p based on the current A_p and B_p, the loop delay factor L, and the statistic U_2;

computing the updated B_p based on the current A_p and B_p, the loop delay factor L, and the statistic U_2; and

computing the updated γ_p based on the current γ_p, the loop delay factor L, and the statistic U_1.

17 ~~18.~~ The apparatus as claimed in claim 16 ~~17~~, wherein the processor updates the parameters A_p, B_p and γ_p by the equations::

$A_p^{'} = A_p - \mu \cdot B_p \cdot U_2^{*} \cdot L \cdot L$;

$B_p^{'} = B_p - \mu \cdot A_p \cdot U_2 \cdot (L \cdot L)^{*}$; and

$\gamma_p^{'} = \gamma_p + \mu \cdot U_1 \cdot L^{*}$

where $A_p^{'}$, $B_p^{'}$ and $\gamma_p^{'}$ are the updated values, A_p, B_p and γ_p are the current values, and μ is a preset step size parameter.

18 ~~19.~~ The apparatus as claimed in claim 11 ~~12~~, wherein the characteristic signal is derived by taking the square of an envelope of the modulated signal.